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A corotational triangular facet shell element for geometrically nonlinear analysis of thin piezoactuated structures

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Abstract

A simple and effective corotational triangular facet shell finite element is proposed for the geometric nonlinear analysis of thin piezoactuated structures. The structures under investigation are laminated shells composed of elastic layers and sensory/active piezoelectric layers, perfectly bonded to each other. A polar decomposition-based corotational framework is adopted. By filtering out large rigid body motions from structural displacements, this framework allows (i) to account for arbitrarily large displacements/rotations, provided strains are small, and (ii) to use existing and high-performance linear elements as core-elements. Within the classical laminated plate theory, the small strain core element formulation based on superposition of OPT membrane and DKT plate element is used, along with a layer-wise constant interpolation of the transversal component of the electric field. Numerical simulations dealing with benchmark problems and applications of technological interest prove accuracy and effectiveness of the proposed formulation.

Keywords: Piezoactuated structures, piezoelectric laminates, nonlinear finite elements, corotational formulation, large displacements and rotations, polar decomposition

1. Introduction

Piezoelectric sensors and actuators have been widely considered by researchers in the last decades, especially for the design of passive, semi-active and active shape and vibration control schemes of thin structures, due to their characteristics of easy integrability in the host structure, light weigh, low price and prompt dynamic response. Many linear theories, formulated in the framework of small displacements, have been reported in the literature for the analysis of the static and dynamic behaviour of piezoactuated beams, plates and shells. Comprehensive reviews can be found in [1, 2, 3, 4].

Piezoatuated structures are usually quite thin, and may undergo significant deflections. This is the case, e.g., for energy harvesters comprising piezoelectric laminates [5] or PVDF flags [6], piezoelectric transformers [7], piezoelectric fans [8], piezoelectric valves [9], piezoelectric actuators for shape control of deployable and inflatable structures with application to space systems and antennas [10, 11]. In general, the hypothesis of small displacements